Hermetic, Bioinert Ultrananocrystalline Diamond Coatings to Enable a Retina Prosthesis

Scientific Achievement

Ultrananocrystalline diamond (UNCD) coatings may enable a whole new generation of biomedical devices implantable in the human body. Specifically, UNCD hermetic, bioinert coatings can be used for encapsulation of a Si microchip, which is the critical component of a retina prosthesis implantable on the human retina to restore sight to people blinded by retina degeneration (e.g., retinitis picmentosa and macular degeneration). The artificial Retina Project is supported by DOE-Office of Biomedical Engineering Research, which integrates several national laboratories, universities and a company (Second Sight). The main goal of the artificial retina project in Argonne is to develop UNCD films as hermetic bioinert/biocompatible coatings for encapsulation of the Si-based microchip that will be an integral part of the retinal prosthesis. To reach this goal, the UNCD synthesis conditions are optimized by investigating the growth parameters (e.g., microwave plasma power, chemistry, and substrate temperature), geometrical arrangements of samples in the MPCVD reactor, growth time, substrate bias, and surface treatment. Recent work focused on growing UNCD films on high conductivity (HC) Si in a 6" diameter microwave plasma-assisted chemical vapor deposition system to test a new geometry for positioning the samples in order to improve film thickness uniformity (Figure 1), while working on conditioning an 11" diameter plasma system. All films were grown under the same conditions (i.e., 1 % H_2 in the Ar/CH_4 (1%) plasma mixture (Figure 2), and nominal 400 ˚C substrate temperature). All films exhibited the Raman signature of low temperature UNCD.

Electrochemical tests on the UNCD were performed on both short and mid-term tests (Figure 3). Leakage current (I_l) vs. DC voltage measurements at +5 volts for midterm tests showed the leakage current I_l was initially ~ $2x10^{-7}$ A/cm^2, and then decayed to ~ 1 $x10^{-7}$ A/cm^2.

UNCD thin films were also implanted into rabbit eyes, followed by extraction after six months and characterization via SEM, XPS, and AFM analysis. Results from AFM force curves indicated that there is no soft matter on the surface of the UNCD exposed to rabbit eye which showed that UNCD is biostable and biocompatible. In addition, XPS analysis showed not noticeable chemical reactions on the surface of the UNCD-coated Si ships implanted in the rabbit's retina.

Significance

The development of the hermetic, bioinert UNCD coatings is critical to enabling the retinal implantation of the prosthesis. In addition, the development of UNCD coatings for this specific biomedical device opens the way for a whole new generation of biomedical devices that require bioinert/biocompatble coatings.

Performers

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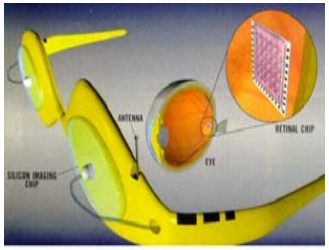
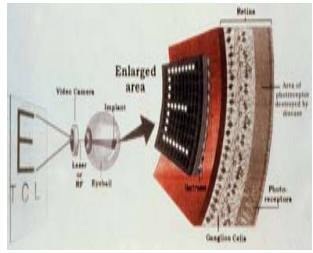
Motivation/Impact

- **UNCD enables a whole new generation of biomedical devices implantable in the human body**
  - **Develop hermetic/biocompatible UNCD thin films as encapsulation coatings for artificial retina microchip to enable implantation of Si microchip on human retina to restore sight to people blinded by retina degeneration**



Overall concept of Retinal Prosthesis for sight restoration to people blinded by retinitis picmentosa and macular degeneration

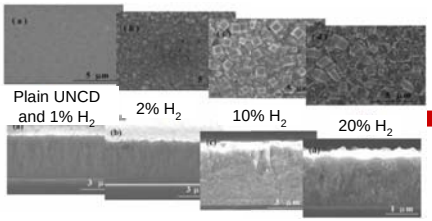


Functional Principle of Retinal Prosthesis

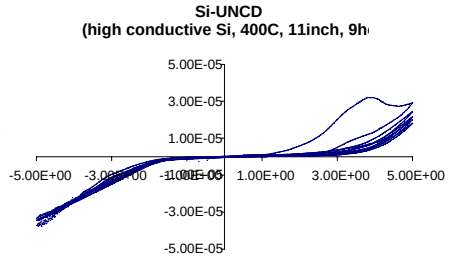
74 year old man see and recognizes objects after 55 years of total blindness
(six persons currently on clinical trials)

Major Accomplishment

Effect of H_2 addition to growth Plasma on UNC coating microstructure and GB bonding



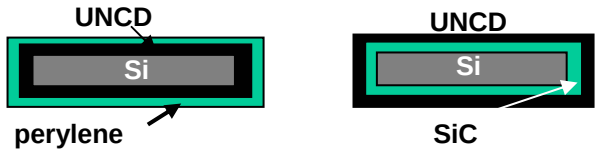
Hydrogen incorporation into GB satisfy dangling bonds resulting in reduction of leakage current in electro-chemical environment such as eye saline solution



GB-Hydrogen incorporated UNCD Coating exhibits low leakage current In saline solution

Future Work

- **Explore UNCD/perylene and UNCD/SiC heterostructures as hermetic /biocompatible coatings**



- **Perform *in vivo* tests of UNCD coatings in rabbit eyes**
- **Perform fundamental and applied research to develop integrated coupling capacitors based on medium or high-dielectric constant thin films (preferable involving bioinert, biocompatible thin films) for input/output signal into microchip**

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